

Growth Response of Tilapia Fed Diets Rich in High-Lysine Corn and Corn Gluten

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ABSTRACT. The purpose of this study was to find out if fish meal is necessary in tilapia diet for good growth response. Five experimental diets (32% protein) containing 46-51% high-lysine corn, 20% corn gluten meal, supplemented with soy grits and synthetic amino acids,

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with and without fish meal were formulated. The diets were fed to tilapia with average initial weight of 13 g for 70 days in aquaria. Weight gain expressed as percentage increase after 70 days or as grams/day, feed conversion ratio, and protein efficiency ratio were equal ($P > 0.05$) to a commercial feed (36% protein) for all experimental diets. It appears that 32% protein diets with 46-51% high-lysine corn and 20% corn gluten meal were adequate for tilapia based on weight gain, feed conversion ratio, and protein efficiency ratio, and that fish meal is not necessary for tilapia feed to obtain good growth response. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <<http://www.haworthpressinc.com>>]

KEYWORDS. Tilapia, high-lysine corn, corn gluten meal, synthetic amino acids, meat and bone meal, fish meal, soy grits, weight gain, feed conversion ratio, protein efficiency ratio

INTRODUCTION

Although normal corn is deficient in lysine and tryptophan for humans, nonruminant animals, and fish, high-lysine corn contains higher levels of lysine and tryptophan compared with normal corn (Mertz et al., 1964). Use of high-lysine corn instead of normal corn can reduce protein supplement for swine feed. Since fish require a higher percentage of protein than swine, it is advantageous to use high-lysine corn instead of normal corn so that protein supplementation can be reduced.

The wet milling process separates corn into starch, germ, protein, and fiber fractions. Corn gluten meal which contains more than 60% protein is the major protein fraction. As the demands for fuel ethanol and high-fructose corn syrup increase, more starch and more corn gluten meal are produced. It is important to find new uses for corn gluten meal in addition to traditional use in cattle, swine, and poultry feeds.

Use of synthetic amino acids in fish feed makes it possible to have a wider choice of feed ingredients and potentially lower feed cost. Viola et al. (1994) studied growth response of hybrid tilapia fed two levels of lysine at three levels of protein. Lee and Bai (1997) included synthetic arginine, isoleucine, and methionine to study hemoglobin powder as a dietary protein source for juvenile Nile tilapia.

Tilapia (*Oreochromis niloticus*) is a warmwater fish with mild flavor, resistance to disease, and has high yield potential. Most commercial fish feed contains fish meal, which is expensive and frequently imported. Replacement of fish meal with plant protein sources in fish feed has been an important

objective of many studies (Tacon and Jackson, 1985; Webster *et al.*, 1992; Morales *et al.*, 1994; Wu *et al.*, 1995, 1996). Our goal was to find ingredients that are readily available and relatively inexpensive for fish feed without fish meal. Since lipid is a relatively expensive ingredient in fish feed, two levels of lipid were included to arrive at optimal growth of tilapia at reduced cost. The purpose of this study was to investigate the growth response of tilapia with initial weight of 13 g to diets containing 46-51% high-lysine corn and 20% corn gluten meal with and without fish meal or meat and bone meal to see if fish meal is necessary for tilapia.

MATERIALS AND METHODS

The ingredients for the experimental diets were mixed and fed into a Leistritz Micro 18GL30D twin-screw extruder (Somerville, NJ). Five diets were prepared: a high-lysine corn diet (H), a fish meal based diet with (HFII) and without (HF) increased lipid, meat and bone meal diets with (HMBII) and without (HMB) increased lipid (Table 1). The reference diet was Purina 5144 Catfish Cage Chow, a 36% protein pellet containing soybean meal, corn, meat and bone meal, fish meal, brewers' dried yeast, animal fat, wheat middlings, dry whey, vitamins and minerals (St. Louis, MO). The diets in Table 1 were formulated to contain 32% protein that met the amino acid requirement of tilapia (Santiago and Lovell, 1988). The reference diet P5144 is a good performing feed with a guaranteed minimum protein content of 36.0% (actual protein 37.9% in Table 1). We chose P5144 as a reference because we were not able to find a suitable good performing feed containing 32% protein.

Fifteen tilapia with average initial weight of 12.7-13.2 g were stocked in 114 L aquaria in triplicate for each diet. Each group of fish were fed twice daily and weighed every two weeks. The amount of feed offered per day was 8.5% of body weight at start, 8.3% the next day, 5.7% at two weeks, 4.94% at four weeks, 3.97% at six weeks, 3.5% at eight weeks, and 2.72% at end of the feeding experiment (ten weeks). The feeding schedule was based on best available data from past performance of feeding tilapia for optimal growth (Wu *et al.*, 1998).

Dissolved oxygen, water temperature and pH were measured daily; total ammonia-N, nitrate-N, nitrite-N, alkalinity and hardness were measured weekly. The average (\pm standard deviation) water quality parameters were: dissolved oxygen, 5.8 ± 0.7 mg/L; temperature, $28.5 \pm 1.1^\circ\text{C}$; pH, 7.6 ± 0.3 ; total ammonia-N, 1.16 ± 0.80 mg/L; nitrate-N, 15.3 ± 2.8 mg/L; nitrite-N, 1.1 ± 1.0 mg/L; alkalinity, 287 ± 13 mg/L as calcium carbonate; and hardness, 274 ± 7 mg/L as calcium carbonate.

Proximate compositions (nitrogen, ash, crude fiber, and moisture contents)

TABLE 1. Percent and proximate compositions (as-is weight basis) of experimental and reference diets

Ingredient	Diet ^k					Reference
	H	HF	HMB	HFII	HMBII	
Corn gluten meal ^a	20.00	20.00	20.00	20.00	20.00	
High-lysine corn ^b	48.94	50.91	49.26	47.43	45.60	
Meat and bone meal ^c	0	0	6.00	0	6.00	
Fish meal ^d	0	6.00	0	6.00	0	
Soy oil ^e	0	0	0	2.89	3.03	
Soy grits ^e	26.93	18.95	20.39	19.53	21.03	
Vitamin mix ^{f,h}	0.50	0.50	0.50	0.50	0.50	
Mineral mix ^{g,i}	2.50	2.50	2.50	2.50	2.50	
Tryptosine ^{e,j}	0.97	1.12	1.26	1.13	1.26	
Lysine-HCl ^e	0.13	0	0.04	0	0.03	
Threonine ^e	0.03	0.02	0.05	0.02	0.05	
Proximate composition						
Moisture	9.0 (0.0) ¹	9.3 (0.4)	9.5 (0.2)	8.2 (0.4)	8.7 (0.1)	7.4 (0.0)
Protein, N × 6.25	32.0 (0.3)	32.4 (1.8)	31.6 (0.0)	32.0 (0.2)	32.0 (0.1)	37.9 (0.1)
Crude fat	3.0 (0.1)	3.5 (0.3)	4.2 (0.2)	6.9 (1.5)	6.8 (0.4)	5.1 (0.8)
Ash	4.7 (0.1)	5.2 (0.0)	5.8 (0.0)	5.1 (0.3)	5.8 (0.7)	8.4 (0.0)
Crude fiber	1.8 (0.1)	1.7 (0.1)	1.5 (0.1)	1.7 (0.0)	1.8 (0.0)	2.9 (0.0)
Digestible energy, kcal/g	3.63	3.62	3.58	3.77	3.73	3.59

^aPekin Energy Company, Pekin, IL.^bCrow's Hybrid Corn Company, Milford, IL.^cRochelle Foods Ins., Rochelle, IL.^dZapata Protein (USA), Hammond, LA.^eArcher Daniels Midland Corp., Decatur, IL.^fHoffmann-LaRoche Inc., Paramus, NJ.^gTriple F-Products, Des Moines, IA.^hThe vitamin premix supplied per kilogram diet: vitamin A, 9900 international unit (IU) from vitamin A acetate; vitamin D₃, 2200 IU; vitamin E, 82.5 IU; vitamin B₁₂, 0.014 mg; riboflavin (B₂), 18.2 mg; niacin, 10.7 mg, from niacinamide; d-pantothenic acid, 37 mg, from calcium d-pantothenate; choline, 715 mg, from choline chloride; folic acid, 6.1 mg; d-biotin, 0.17 mg; ascorbic acid, 220 mg, from L-ascorbyl-2-polyphosphate; menadione (K₃), 9 mg, from menadione sodium bisulfite complex; thiamin (B₁), 16.2 mg, from thiamine mononitrate; pyridoxine (B₆), 12 mg, from pyridoxine hydrochloride.ⁱThe mineral premix supplied per kilogram diet: calcium, 4.3 g, from calcium carbonate and dicalcium phosphate; phosphorus, 2.6 g, from dicalcium phosphate; copper, 5.0 mg, from copper sulfate; iron, 41 mg, from ferrous sulfate; manganese, 120 mg, from manganous sulfate; zinc, 115 mg, from zinc sulfate; iodine, 2.5 mg, from ethylenediamine dihydroiodide; cobalt, 1.0 mg, from cobaltous carbonate; sulfur, 153 mg.^jTryptosine contains 10% L-tryptophan and 60% L-lysine-HCl.^kH is high-lysine corn. F is fish meal. MB is meat and bone meal. II is additional soy oil.¹Values in parenthesis are standard deviations.

of diets were determined in duplicate by AACC Approved Methods (AACC, 1995). Nitrogen (N) was measured by micro-Kjeldahl, and protein was calculated by $N \times 6.25$. Fat was determined by acid hydrolysis (AOAC, 1990). Percent ash was determined from the weight remaining after heating the sample for 2 h at 600°C. Crude fiber was measured as loss on ignition of dried residue remaining after digestion of sample with 1.25% H_2SO_4 and 1.25% NaOH solutions under specified conditions. Moisture was from the weight loss after oven drying at 135°C for 2 h. Diets were analyzed for amino acid content. The samples were hydrolyzed by 6 N HCl for 4 h at 145°C (Gehrke *et al.*, 1987), and the amino acids were determined by cation exchange chromatography in a Beckman 6300 amino acid analyzer (Beckman Instruments, Inc., San Ramon, CA). Two amino acid analyses were determined for each diet. Methionine and cystine were oxidized by performic acid before hydrolysis (Moore, 1963). Tryptophan was measured according to a colorimetric method after enzymatic hydrolysis by pronase (Spies and Chambers, 1949; Holz, 1972).

Weight gain was calculated from (final weight – initial weight)/initial weight and expressed as the percentage increase at the end of 70 days. Weight gain was also calculated as g/day on a per-fish basis. Feed conversion ratio was determined as dry feed offered/wet weight gain. Protein efficiency ratio was measured as wet weight gain/protein fed. The digestible energy of the diets was calculated by using values of 4.5, 4.0, and 9.0 kcal/g for protein, carbohydrate, and lipid, respectively (Wang *et al.*, 1985).

The data were treated by analysis of variance. Tukey's Studentized Range Test was used for significant difference ($P < 0.05$) (SAS Institute Inc., 1987).

RESULTS AND DISCUSSION

The experimental and reference diets met or exceeded the amino acid requirement of tilapia (Table 2). The digestible energy of the lower fat diets (HF, H, and HMB) clustered around 3.59 kcal/g of reference diet, whereas diets HFII and HMBII had slightly higher values (Table 1).

Weight gain of tilapia fed different diets (Table 3) ranged from 437-637%. Fish fed the diet with high oil and fish meal (HFII) had highest weight gain whereas fish fed the diet with low oil, no fish meal or meat and bone meal (H) had the lowest value. There was no significant difference ($P > 0.05$) in percent weight gain when fish fed the experimental diets were compared with fish fed the reference diet.

Growth rate of 0.80 to 1.20 g/d (Table 3) was considerably higher than those of Rakocy (1989), Shiau *et al.* (1990) and Jackson *et al.* (1982) and close to those of Lee and Bai (1997). Rakocy (1989) obtained 0.5 g/d growth rate for 5 to 20 g tilapia. Shiau *et al.* (1990) reported a growth rate of 0.16 to

TABLE 2. Essential amino acid composition (g/16 g N) of experimental and reference diets

Amino acid	Diet					Reference	Requirement ^a
	H	HF	HMB	HFII	HMBII		
Arginine	5.4 (0.1) ^b	5.1 (0.1)	5.3 (0.2)	5.2 (0.1)	5.3 (0.0)	6.4 (0.1)	4.2
Histidine	2.4 (0.1)	2.3 (0.1)	2.3 (0.1)	2.4 (0.1)	2.3 (0.1)	2.4 (0.0)	1.7
Isoleucine	4.0 (0.2)	3.6 (0.5)	3.8 (0.2)	4.0 (0.2)	3.8 (0.1)	3.9 (0.0)	3.1
Leucine	11.1 (0.4)	10.8 (0.4)	11.0 (0.3)	11.2 (0.2)	11.0 (0.1)	7.5 (0.1)	3.4
Lysine	6.1 (0.2)	6.2 (0.2)	6.4 (0.2)	6.4 (0.0)	6.4 (0.0)	5.9 (0.0)	5.1
Methionine + cystine	3.7 (0.1)	3.8 (0.2)	3.7 (0.2)	3.9 (0.1)	3.6 (0.0)	3.3 (0.1)	3.2
Phenylalanine + tyrosine	9.3 (0.3)	8.9 (0.3)	9.0 (0.4)	9.3 (0.2)	9.1 (0.1)	7.6 (0.1)	5.5
Threonine	3.7 (0.2)	3.7 (0.2)	3.7 (0.1)	3.8 (0.1)	3.7 (0.1)	3.8 (0.1)	3.8
Tryptophan	1.5 (0.0)	1.5 (0.0)	1.5 (0.2)	1.5 (0.0)	1.4 (0.1)	1.2 (0.1)	1.0
Valine	4.7 (0.2)	4.3 (0.6)	4.7 (0.3)	4.7 (0.1)	4.6 (0.2)	4.6 (0.1)	2.8

^aSantiago and Lovell (1988).^bMean (standard deviation) of two analyses.TABLE 3. Weight gain (WG), feed conversion ratio (FCR), and protein efficiency ratio (PER) of tilapia fed experimental and reference diets^a

Diet	WG					
	Initial weight, g	Final weight, g	%	g/d	FCR	PER
H	12.8 (0.3)	68.9 (4.8)	437 (37)A	0.80 (0.07)A	1.95 (0.11)A	1.46 (0.08)A
HF	13.2 (0.2)	75.8 (10.7)	473 (79)A	0.89 (0.15)A	2.09 (0.29)A	1.36 (0.20)A
HFII	13.2 (0.1)	97.3 (17.3)	637 (127)A	1.20 (0.25)A	1.68 (0.17)A	1.72 (0.18)A
HMB	12.8 (0.1)	76.6 (21.1)	501 (165)A	0.91 (0.30)A	2.03 (0.74)A	1.53 (0.47)A
HMBII	12.9 (0.1)	82.7 (5.5)	540 (46)A	1.00 (0.08)A	1.86 (0.23)A	1.55 (0.18)A
Reference	12.7 (0.2)	89.6 (6.0)	605 (57)A	1.10 (0.09)A	1.88 (0.15)A	1.31 (0.10)A

^aMeans of triplicate (standard deviation) for experimental and reference diets. Weight gain expressed as the percentage increase and in g/d at the end of 70 days. Feed conversion ratio is dry feed/wet weight gain. Protein efficiency ratio is weight gain (g)/(g) protein fed. Numbers followed by different letters in columns are significantly different ($P < 0.05$). H is high-lysine corn. F is fish meal. MB is meat and bone meal. II is additional soy oil.

0.21 g/d for tilapia (*Oreochromis niloticus* × *O. aureus*) fed a 24% protein diet with an initial weight of 5.1 g for 9 weeks in a recirculating system. Jackson et al. (1982) obtained a growth rate of 0.13 to 0.25 g/d for tilapia (*Sarotherodon mossambicus*) with initial weight of 12.3 to 13.5 g fed a 30% protein diet for 7 to 9 weeks in a recirculating system. Lee and Bai (1997)

reported a growth rate of 0.90-1.2 g/d for Nile tilapia (*Oreochromis niloticus*) with initial weight of 6.8 g fed a 40% protein diet for 6 weeks in a recirculating system.

Feed conversion ratios of tilapia fed experimental and reference diets ranged from 1.68-2.09 (Table 3). There was no significant difference ($P > 0.05$) in feed conversion ratios. These ratios compared favorably with those reported by Jackson et al. (1982) and Clark et al. (1990). Jackson et al. (1982) reported feed conversion ratios of 1.66-2.80 when they fed 30-32% protein diets to tilapia with initial weights of 12.3-13.5 g in a recirculating system for 49-63 days. Clark et al. (1990) fed a 32% protein diet to tilapia with initial weight of 9.1-12.7 g for 84 days in marine cages and obtained feed conversion ratios of 2.11-2.26 for 90 and 110% feeding rates.

Protein efficiency ratios of fish fed experimental and reference diets ranged from 1.31 to 1.72 (Table 3). Again, there was no significant difference ($P > 0.05$) in protein efficiency ratios.

The treatment with the highest mean weight gain, the lowest mean feed conversion ratio, and the highest mean protein efficiency ratio was the diet containing fish meal with additional soy oil (HFII). Diet HFII also had the highest digestible energy of 3.77 kcal/g. However, digestible energy may not account for all the difference, because the lowest digestible energy of 3.58 kcal/g was from diet HMB, which contained meat and bone meal, and had intermediate weight gain, feed conversion ratio, and protein efficiency ratio values. Furthermore, diets with high lysine corn (H) and with high lysine corn and fish meal (HF) had higher digestible energy (3.63 and 3.62 versus 3.59) but lower weight gains than the commercial reference diet.

Experimental diets (HF vs. HFII and HMB vs. HMBII) that differed only in lipid contents resulted in equal weight gain, feed conversion ratio and protein efficiency ratio ($P > 0.05$, Table 3). Fitzsimmons et al. (1997) reported that specific growth rates and feed efficiency ratios were not significantly different for juvenile hybrid tilapia fed diets containing 3, 6, and 8% lipids. Takeuchi et al. (1983) found that Nile tilapia required only 0.5% linoleic acid for maximum growth and feed efficiency. Since corn oil contained 47% linoleic acid and soy oil had 50 to 53% linoleic acid (Cocks and van Rede, 1966), all experimental diets met the linoleic acid requirement. Santiago and Reyes (1993) found no significant difference in weight gain for Nile tilapia fed 40 to 44% protein diets containing 1.6 to 7.9% crude fats. Chou and Shiau (1996) reported that weight gain, feed conversion ratio, and protein efficiency ratio of juvenile hybrid tilapia fed 29 to 30% protein diets containing 5% lipid were not significantly different ($P > 0.05$) than those fed diets containing 10, 15, and 20% lipids. Kubaryk (1980) found growth of juvenile *Tilapia nilotica* was inhibited when the total fat content of diet, with

varying oil levels up to 14%, exceeded 7%. Stickney and McGeachin (1984) reported no significant growth differences between 2, 4, 6, 8, 10, 12, or 14% beef tallow diets fed to *Tilapia aurea* fingerlings for 12 weeks. Our experimental diets containing 3.0 to 6.9% fat (Table 1) appeared optimal.

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